TECHNICAL REPORT # 5 #5

Froms The Crawford Hill VHF Club Dates (1970)
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Subjects: A Paraboloidal Reflector Antenna for 1296 mc/s

This report will consider a paraboloidal reflector type antenna suitable for EME communications at 1296 mc/s. Basic design considerations and construction techniques will be presented.
A 20 foot (6.1 meters) diameter, f/D = 0.5, design will be detailed. This size reflector antenna should provide a minimum of 35.0 dB effective gain at 1296 mc/s and make possible reliable echo reception with 500 watts of available r-f transmitting power and a receiving system operating temperature under 300 degrees Kelvin.
The design presented here is slightly different from the original Notes. A more detailed analysis and fine-tuning of the design is included here.

Basic Design Considerations

A paraboloid, parabola of revolution or "dish" can be used as a focussing reflector when suitably illuminated by a feed antenna which has a well defined phase center of radiation, and radiates principally over the area of the reflector surface.
Figure la depicts the basic components of a parabolic reflector antenna, the feed and the reflector, along with support struts. Figure lb is a cross-sectional view through the center of the reflector showing the various factors of interest in the design of any paraboloidal reflector antenna.
The most important consideration of this type antenna for EME purposes is that it provides maximum effective gain for transmitting and maximum gain/antenna temperature ratio for receiving.
As will be seen. these requirements are somewhat paradoxical.

Effective Gain

Maximum effective gain of an aperture antenna, of which the parabolic reflector antennas is a member, can be expressed as the product of an efficiency factor times the maximum possible aperture area gain.

$$\text{Effective Gain} = \eta \left(\frac{4\pi A_o}{\lambda^2}\right)$$

Where the same length units (feet, inches, meters, etc) are used to compute the physical aperture area, and for the free-space wavelength x Gain in these Reports will always be referenced to an isotropic radiator whose gain is defined as equal to I.
For a circular aperture, the same gain expression may be written as:

$$\text{Effective Gain} = \eta \left(\frac{\pi D}{\lambda}\right)^2$$ (x 10 log in dBi)

where D is the reflector diameter as shown by Figure lb.
Gain in decibels above isotropic is 10 x log10 G (above).

For a paraboloidal reflector antenna with front, prime focus, feed, the total efficiency, , is essentially a product of two factors: (1), the fraction of the total power radiated by the feed which is intercepted by the paraboloid and is thus made available to the aperture to generate gain; and (2), the efficiency with which the paraboloidal reflector concentrates the available power in the desired forward direction into a pencil beam of radiation.

The significance of the first factor will be clearly understood from the cross-sectional drawing of Figure lb. Here most of the radiated energy from the feed impinges upon the reflector surface and is focused by reflection into parallel rays of energy in the forward direction (to the right in the Figure). A small portion of the radiated energy from the feed extends beyond the edge of the reflector as shown by the shaded area in the Figure. This energy is lost and cannot contribute to the gain of the antenna in the forward direction. This lost energy or power is called **spillover.** It will however contribute to unwanted rear radiation in the transmit mode and to the antenna temperature in the receive mode.
The first factor then is simply the ratio of energy intercepted by the reflector to the total energy radiated by the feed.

The second factor, (2) is termed aperture illumination efficiency and is a term commonly used with high-gain large-aperture antennas to denote how effective the aperture area is in producing gain. The actual aperture area of a paraboloidal reflector antenna is the plane area enclosed by the rim of the reflector. Aperture theory tells us that the effectiveness of this area in producing gain is related only to the way in which the available energy is distributed over that aperture, in both phase and amplitude.

Ideally, for maximum possible gain, the aperture distribution of energy should be uniform in both amplitude and phase. The geometrical properties of a parabolic reflector fed by a source which itself has a well defined phase center located at the focal point of the reflector, results in a constant phase of all energy from the feed over the aperture area, i.e., the distance from the focal point to anywhere on the aperture plane is constant. And the amplitude distribution of energy over the aperture plane is largely determined by the radiation charactistics of the feed antenna. For best efficiency, the feed antenna is always aligned with its direction of maximum radiation into the center (vertex) of the paraboloid. The resultant energy distribution will therefore always be maximum at the center of the aperture area, decreasing in some fashion towards the edge (rim) of the reflector. This unavoidable tapering of energy distribution results in an aperture illumination efficiency factor of slightly less than unity. There is an additional tapering of the feed energy which is due simply to the geometry of the paraboloid.

Numerically, this additional tapering is the ratio of the distance, R, from the focal point to the center (vertex) of the reflector (i.e., the focal length), to the distance to any other point on the reflector surface, or (1 + cos(0))/2. Figure 2 shows a plot of the additional space tapering v.s. f/D, the focal length to diameter ratio of the reflector. The total energy tapering is the combined feed radiation and space tapering.

Efficiency Computations:
To bring into focus these efficiency factors relating to the gain of a paraboloidal reflector antenna, a specific feed must be selected. This report will use only the dual-mode (IMU) type feed which is the highest efficiency small aperture feed antenna known to date. All results obtained will be for this particular feed, whose measured radiation characteristics are shown by Figure 3. For computational purposes, an approximate mathematical model is also shown. Note that the model feed radiation pattern is taken to be circularly symmetric which is correct at least over the reflector intercept region and only very slightly in error in side and back radiation.

All mathematical relations used to determine efficiency factors and spillover temperature are in Appendix A.
Spillover and illumination distribution efficiency have been computed and plotted separately on Figure 4, together with the combined total efficiency. Note the broad maximum in efficiency around an f/D ratio of 0.56. These calculations predict that a maximum possible effective antenna gain will be the aperture area gain reduced by the efficiency factor, 0.785 (- 1.05 dB), in this case. Such high efficiency is never realized in practice owing to at least the following detrimental effects: inaccurate reflector surface, poor reflecting surface material (transmission leakage), blockage and scattering from the feed and feed support struts, cross polarized radiation of the feed and heat, losses mainly in the feed itself.

In practice a total efficiency factor of -1.8 dB or 66% can be achieved with care and good materials. The discrepancy of 0.75 dB can be accounted for among the above mentioned detrimental effects.
Figure 4 may also be used to determine the penalty to be paid when using the dual-mode feed with a reflector having an f/D other than the optimum 0.56. For example, if you have a reflector with an f/D of 0.4, the expected loss of antenna gain will be very nearly 0.5 dB.because of antenna noise considerations, it is always best to error on the side of lower than optimum f/D with virtually any feed arrangement. Antenna Gain/Temp ratio will be considered in the section on antenna temperature. Note that Figure 4 also includes an antenna temperature curvy for spillover to the warm Earth only.

Antenna Temperature and Optimization of Gain/Temp.
The effective antenna temperature presented at the feed connection (port) is the aggregate of several sources. The most significant are spillover from the feed, scattering from feed support struts, ' or any other radiation blockage, diffraction

around the rim edge of the reflector, and heat losses mainly in the feed antenna itself. In addition there can be noise leakage through imperfect surfacing material.

All noise sources except heat losses are in some way related to the position (pointing) of the antenna. This is especially true of discrete celestial sources such as Galactic noise, Radio Stars, the Sun and the Moon. Of these the Sun is by far predominant. having an effective temperature of about 100,000 degrees Kelvin at 1296 mc/s compared with 210 deg K. for the Moon. Man made noise sources, which can be troublesome at times, are not considered in this report. In general most man made noise sources such as automobile ignition and motor commutator sparking have a very small noise component at 1296 mc/s.

At low elevation pointing angles there is also a significant increase of antenna noise because the main beam of the antenna is partially in view of the Warm Earth. Also at low elevation angles more Earth atmosphere is intercepted by the main beam which causes and additional small increase in antenna noise. For these reasons EME communications with the Moon at rise or set times can be compromised by this additional noise.

Spillover noise can be easily computed and may be controlled by proper selection of the reflector f/D ratio. For a given feed radiation pattern, decreasing f/D will also decrease spillover noise, see Figure 4.

In view of the low noise receiver devices available at present times (1980s) it is important to minimize all antenna noise without greatly compromising antenna gain. Feed antenna heat losses can be decreased by the use of highly conductive material in construction, copper instead of brass, care in construction to minimize solder on all active antenna areas along with good designs where r-f current paths are not interrupted by soldered seams where possible. Broad band feed designs (low-Q) are also potentially less lossy.

Strut scattering can be minimized by the use of dielectric struts instead of metallic ones. Reflector surface leakage can be virtually eliminated by using material with transmission loss greater than 30 dB, and with minimum seams and joints.

A realistic approach to optimizing the paraboloidal reflector f/D ratio is to assign some reasonable estimate to all other antenna noise except spillover, and then by computation maximize the antenna gain squared divided by Tsys, the system operating temperature. For the EME echo path the same antenna is usually used for both transmitting and receiving, therefore the square of the antenna gain (or just efficiency squared) should be used. The system operating temperature consists of the sum of the total antenna noise plus the receiving system total noise. The factor gain squared divided by Tsys appears in the EME system receiver output S/N ratio (see Report *3).

Maximizing this factor will therefore optimize the S/N for best reception of echoes.

If the system operating temperature, Tsys is written as the sum of Tsp (spillover temperature) all other sources (call this Tc), then direct evaluation of the optimum f/D v.s. Tc can be made, and is graphed by **Figure 5.**

A very useful example is for Tc = 110 deg. K. where an optimum f/D = 0.5 is indicated. Tc includes a receiving system with about

1 dB NF (75 deg K) and the remaining 35 deg K mainly due to heat losses in the feed (35 deg. K corresponding to 0.5 dB loss, a very reasonable estimate considering interconnect between feed and receiver as part of the system). The loss in antenna efficiency (one way) at f/D = 0.5 compared with the maximum possible efficiency at f/D = 0.56 is only 0.1 dB. The total improvement in 8/N is only of the order 0.1 dB, but represents a positive improvement.

This f/D optimizing process clearly indicates that the choice of f/D for the paraboloid is mat critical but should be made towards a lower value to obtain the meager benefits. It does point out however that decreasing other sources of antenna noise as well as receiver noise effects the choice of an optimum f/D ratio.

The Dual-Mode Feed Antenna

The dual-mode (W2IMU) feed design embodies all the best attributes of a high efficiency feed antenna; single circularly symmetric beam radiation, virtually no side or back radiation, a well defined phase center and a small aperture to minimize blockage. This design in circular waveguide permits linear or circular polarization to be readily implemented.

Figure 6 contains complete information for constructing this feed for circular polarization at 1296 mc/s. It may be readily scaled to other bands except for the 30 degree conical flare angle which remains fixed. The term dual-mode refers to the excitation of two circular waveguide modes in the structure, the dominant TE11 mode and the TM11 mode. These modes when combined in proper phase and amplitude at the small feed antenna aperture result in the desirable radiation characteristics obtained. Other type feeds can give similar results but may be more difficult to adjust and construct.

Reflector Surface Error Effects

An exact paraboloidal surface can be described mathematically as shown by Figure la, with dimensional coordinate system centered at the vertex of the reflector surface. By setting either X or Y equal to zero, the more familiar plane or two-dimensional parabolic arc is obtained which can be used to layout the required curve for constructional purposes, see Figure 7.

A large paraboloid is very difficult to construct accurately and so some determination of the effects of inaccuracies must be included in estimating the effective antenna gain. Any departure from an exact paraboloid will always result in loss of gain and increased sidelobes in the radiation characteristics of the antenna system. Figure 8 shows a set of curves which relate the loss of gain to r.m.s. surface deviation. This implies a surface, which on the <u>overawe</u> is an exact paraboloid but has bumps and depressions above and below the average surface. These bumps and depressions cause changes in phase length from the focal point to the aperture plane and thus cause a departure of phase over the aperture area from the desired uniform distribution. Aperture theory indicates that radiation from a large aperture is more sensitive to phase distribution than amplitude distribution which reinforces the need for accuracy of

the reflector surface.
R.m.s. means root-mean-square and the r.m.s. surface deviation may be obtained by the following procedure, though very difficult to perform in a practical situation.

Divide the reflector area into a large number of equal area sections. Then measure the deviation in inches at the ~enter of each subsection from the exact surface. Take each deviation measurement. Square it, add all the squares together, take the square root of the sum and divide by the total number of measurements. The result is the r.m.s. surface deviation in inches which may be used with Figure 8 to estimate the loss in gain at 1296 mc/s. Additionally, a measure of the correlation factor C should be made which is the extent or size of the bumps. This is an equally difficult measurement to perform but some idea of C can be found by careful scrutinization of the deviation data, provided that a large enough number of measurements were performed.

Figure 8 clearly reveals, however, that even severe bumps which are not large in area cause little effect, but as the bump size approaches a wavelength, the loss in gain becomes appreciable.

Another form of surface distortion which can be even more devastating is warp age, and deviation from an exact paraboloid curve in the radial direction. Both of these effects can result in severe loss in gain since large area phase errors are involved.
For example, a smooth departure from center to edge of the reflector by an eighth wavelength (1.13 inches at 1296mc/s) will degrade the antenna gain by about 1 dB. If the surface error at the rim is a quarter wavelength, the gain will degrade by 4 dB !

It cannot be overstressed, that the performance of a reflector antenna is greatly dependent on the care and accuracy of construction of the reflector surface and material used, as well as the choice of feed antenna.

A very bad surface can be detected by poor gain performance as well as assymetric beam shape, even beam splitting and skewing off axis. Radiation pattern measurements of the antenna system, though difficult to perform with large EME antennas, can be very helpful for diagnostic purposes if antenna performance is below par.

A common condition which exists for home made reflectors is that the average surface may actually have a slightly different focal point than the design value, due to inaccuracies in construction. The result is an out-of-focus antenna system with poor gain. It is always advisable when testing a new reflector antenna to probe the focal point with the feed by moving it toward the reflector and away from the reflector by at least a wavelength, while monitoring the antenna gain. A single peak in gain should occur. If two peaks appear, or the peak in gain is smeared (no distinct peak observed), then the reflector surface most assuredly has Inaccuracies and should be fixed or redone. A movement of the feed +/- one half wavelength should produce a noticeable (1 dB at

least) change in gain with a good reflector surface.
Misalignment of the radio beam with the expected centerline of the paraboloid (optical boresight) indicates a distorted reflector surface, assuming that the feed is centered on the reflector axis (centerline).
From the above considerations, it should be clear that construction of a large reflector should emphasize accuracy of the paraboloidal shape with surface roughness a secondary consideration, provided the roughness is fine grained (small area bumps).

Surfacing, Material
A very important consideration in the construction of any reflector antenna is the actual reflector surface material and how it is applied. Ideally, the surface should be conductive and continuous over the entire reflector surface. It should have a thickness of several 'skin depths' at the operating frequency. One 'skin depth' of aluminum at 1296 mc/s is about 0.0001 inch. Any of the readily available aluminum foils is adequate.
The material need not have a high electrical conductivity because a reflector is a low-Q device with surface currents well distributed. Iron, copper or aluminum are acceptable for surfacing and readily available in foils and mesh form.

These include window screening, hardware cloth, expanded metals sheet, perforated sheet, fencing, etc. Materials such as screening and hardware cloth which are constructed of wires forming a square mesh may be evaluated for transmission loss with the aid of **Figure 9.** This nomograph relates radio transmission loss through the material as a function of the physical dimensions of the mesh and wires. Since power transmission through the reflector is lost, like spillover, the degradation in antenna gain is readily evaluated. **Figure 9** includes computed loss of gain, along with transmission loss.

In recent times, expanded aluminum sheet has become readily available and is used extensively in home TYRO systems. This material should not be overlooked as it is perhaps the only material which will deform in two dimensions to permit very accurate surface contours to be formed. Another material which offers possibilities for light-weight solid-surfacing is a building trade insulation siding material consisting of a sandwich of two layers of aluminum foil with a urethane foam core. It is available in 4 by 8 foot sheets either 1/2 or 3/4 inch in thickness, is easily cut with a knife and may be bent moderately in one plane only.

In addition to loss of gain from leakage through the reflector surface, there is also a penalty in antenna temperature because leakage also takes place in the reverse direction allowing the feed to 'see' the temperature behind the reflector attenuated by the transmission loss. The worse case would be for high elevation pointing angles where the warm Earth is behind the reflector. In this case for a transmission loss of 10 db, the antenna temperature will be raised by approximately 250/10 deg. K, or 25 degrees K. In view of modern low noise .device

technology, the receiving degradation due to this additional noise temperature must be considered significant.
Materials whose mesh shape is not square, such as hexagonal fencing (chickenwire), may be evaluated by considering an equivalent geometric square, or by direct measurement of transmission loss through a large sample area. In general, if the largest dimension of the mesh hole exceeds one inch, the material may be marginal or unacceptable for a reflector at 1296 mc/s.

Three quarter inch hexagonal chicken wire fencing, for example, has a measured - 10 dB transmission loss at 1296 mc/s and should be considered marginal for a high efficiency system. It should also be pointed out that although cross over points in most mesh material are electrically bonded, it is not necessary. It should also be pointed out that heavily corroded materials are good reflectors until the actual metal has been completely eaten away. Coatings such as paint, sealers or even corrosion cause no degradation because their thickness is a very small part of a wavelength, and even though the coating may be a lossy material as a dielectric, there is virtually no loss because the electric field at the surface of a reflector is virtually zero.

When applying surface material to the reflector support frame, additional precautions should be observed. In general, the smallest dimension of a section or panel should be **larger than a wavelength,** or at least 12 inches at 1296 mc/s. Also, because the feed illumination is strongest at the center of the reflector, this area should be given special attention as to accuracy and with the largest available pieces of material. In the sectioned (petal shaped) design described in this report, the central area should not be covered by extending the wedge shaped pieces to the center point. Rather, the wedges should be truncated where the width is no less than about 12 inches (for 1296 mc/s). Inevitably there will be seams or joints where panels meet. In general an electrically bonded seam is desirable. However, since the free-space impedance is high (377 ohms) the actual seam need not be bonded provided that an overlap of one quarter wavelength (2.25 inches at 1296 mc/s) is formed. This overlap, if very close spaced, is essentially a low impedance , parallel plate transmission line transformer which reflects a short circuit at the surface gap. If the sections of surfacing material are very large then butt seams which are neither bonded nor overlapped will provide satisfactory performance. The butt joints should be reasonably close spaced to prevent excessive leakage through the slot.

Feed Support Struts

A necessary part of a front fed parabolic antenna design are the feed support struts. These struts must be located directly in the active radiating region of the antenna and thus must be given due consideration because of the potential aperture area blockage which reduces the effective gain, and scattering which increases antenna noise. The effect can be even more severe if the support

struts or any other members, such as feed line or brackets are permitted to block and scatter feed radiation.
For these reasons it is highly recommended that support struts be mounted well out of the region around the feed aperture, at least in the frontal hemisphere around the feed. The struts should also extend out to the rim of the reflector to effect as little blockage to the feed illumination as possible.

No more than three struts equally spaced are required. With an az-el antenna mount, the struts should be placed so that only one strut is in tension when the antenna is at low elevation angles. Struts may be made from thin wall aluminum (hard grade) tubing just large enough in diameter to support the feed assembly. Alternatively, the struts can be made from rigid PVC water drain
pipe material. The use of dielectric material for the struts is highly recommended to greatly reduce blockage and scattering from the struts. A larger diameter PVC tube can be used for strength and tapered at the ends to minimize wind loading.

Reflector Construction

The following information on reflector construction may be used as a guide. This particular method of surface design uses the gored pattern or petal design in which cylindrical parabolic sections (the petals) provide an easy way to used surface material which can only be curved in one dimension, such as sheet or mesh material, see Figure 7. This construction method leads to regular phase errors over the surface (mainly towards the rim) which degrades the antenna gain. Figure 10 can be used to determine the degradation from physical parameters.

The design presented here limits the maximum degradation to 0.25 db. In the 20 foot diameter reflector design presented here. a total lb trussed ribs (O/D = 0.5) is suggested in order to accomodate available material size in the U.S.A.The individual petal layouts are limited to 4e inches in width by *96 i*nches in length (see Figure 7). The actual focal length of the reflector will be slightly less than the expected 120 inches due to the modified surface design. The expected nominal focal length will be approximately 117 inches for this design. As suggested earlier in this report, the focus of any new reflector should always be probed with the feed to find the optimum location of the feed antenna.

The backup support structure used here is the trussed rib and central hub method where the hub diameter is constrained to be about 48 inches in diameter. Figure 7 suggests the form of construction where aluminum tubing and gusset plates are used extensively, held together with pop-rivets. The hub may be formed into a 16 sided polygon from tubing bent with the aid of a tool called a "hickey", used by electricians to bend electrical conduit and which may be rented from most electrical supply
houses.

The rim of the reflector is not circular but made from straight 48 inch lengths of tubing to form a 16 sided polygon Additional straight spreaders maybe used between the ribs and towards the rim to support the surface material from sagging.
The parabolically curved member of the rib should be made from a softer grade aluminum tube and carefully bent into the

Approximate parabolic arc to reduce stress spring-back in the trussed rib assembly. A wooden jig should be made and used to assemble the trussed ribs to ensure that all are identical and of
accurate shape. Those ribs assigned to support the feed struts may be strengthened with additional trussing and perhaps a double back member.
When petal sections are used with no overlaps at the rib seams, the exact shape of the section is not exactly triangular but has slightly curved edges along the long sides. The exact layout shape is shown by Figure 11, with necessary equations to compute dimensions.

Antenna Mountina and Drive Considerations

Large antennas primarily intended for EME communications should be mounted no higher above the Earth than necessary. Although elevation-over-azimuth mounts are popular, the polar mount is highly recommended for simplicity of the Moon orbital tracking drive mechanism, and accuracy of tracking.
For any given installation. the height of the antenna will be determined by foreground clearance in the Moon orbital direction. Foreground clearance usually considers buildings. Trees or other
obstacles which can block and scatter radiation from the antenna.

The radiation characteristics of a large aperture antenna can be described as a circular tube having a diameter equal to the largest extent of the aperture. and extending directly out in front of the aperture by at least 10 aperture diameters or more. this cylindrical volumetric space can be used to determine if an obstacle is in the radio beam.
The minimum height of the antenna should be approximately half the aperture diameter to permit easy access to the feed and also near horizon pointing at Moon rise and set, for maximum DX.
In general, hill top locations are desirable for maximum DX conditions at Moon rise and set, but are also more vulnerable to radio receiver interference from nearby sources, TV or FM broadcast harmonics, RADARS, commercial mobile radio service, industrial r-f heating devices, etc.
A careful survey of available space should be made before installation of an EME mount and antenna to allow for maximum Moon orbital access with minimum blockage and also minimum friction with family and neighbors. -Even though r-f fields the beam of a large aperture antenna are diluted, pointing such antennas at occupied buildings can be a serious matter with which to contend, and should be avoided.

Summary

Design information and construction suggestions have been presented for a 20 foot parabolic reflector antenna employing the dual-mode (IMU) feed. The reflector design presented is suggested to make best use of surfacing materials such as screen mesh and sheet which cannot be contoured in two dimensions but are very well suited to the cylindrical petal surface design.
The basic purpose of this material is for use in realizing

high-gain low-noise antenna suitable for EME communication. As in all UHF design and construction, careful attention to detail and accuracy are the key to a successful hardware project.
For construction of a large antenna of the type described in this report, the major factors in the order of their importance are: physical rigidity and strength to withstand environmental effects and maintain reflector shape, accuracy of parabolic surface, low leakage surface material, minimmmum heat losses (especially in feed and interconnect cables), high efficiency feed (IMU type recommended), and minimimum strut blockage.

APPENDIX - A

For a paraboloidal reflector antenna geometry and feed which has a circularly symmetric radiation characteristic, the spillover and aperture illumination efficiencies may be computed thus:

$$\eta_{sp} = \frac{\text{Power from feed intercepted by reflector}}{\text{Total power radiated by feed}} = \frac{\int_0^{\theta_0} |E(\theta)|^2 \sin(\theta)\, d\theta}{\int_0^{\pi} |E(\theta)|^2 \sin(\theta)\, d\theta}$$

and,

$$\eta_{illum} = \frac{\text{Power radiated in direction of the main beam}}{\text{Total power radiated by aperture as a point source}} = 2\cot\left(\frac{\theta}{2}\right) \frac{\left| \int_0^{\theta_0} E(\theta) \tan\frac{\theta}{2}\, d\theta \right|^2}{\int_0^{\theta_0} |E(\theta)|^2 \sin(\theta)\, d\theta}$$

where θ_0 is the angle to the edge of the reflector (see Figure 1b). For any given f/D ratio;

$$\theta_0 = 2 \arctan\left(\frac{1}{4 f/D}\right)$$

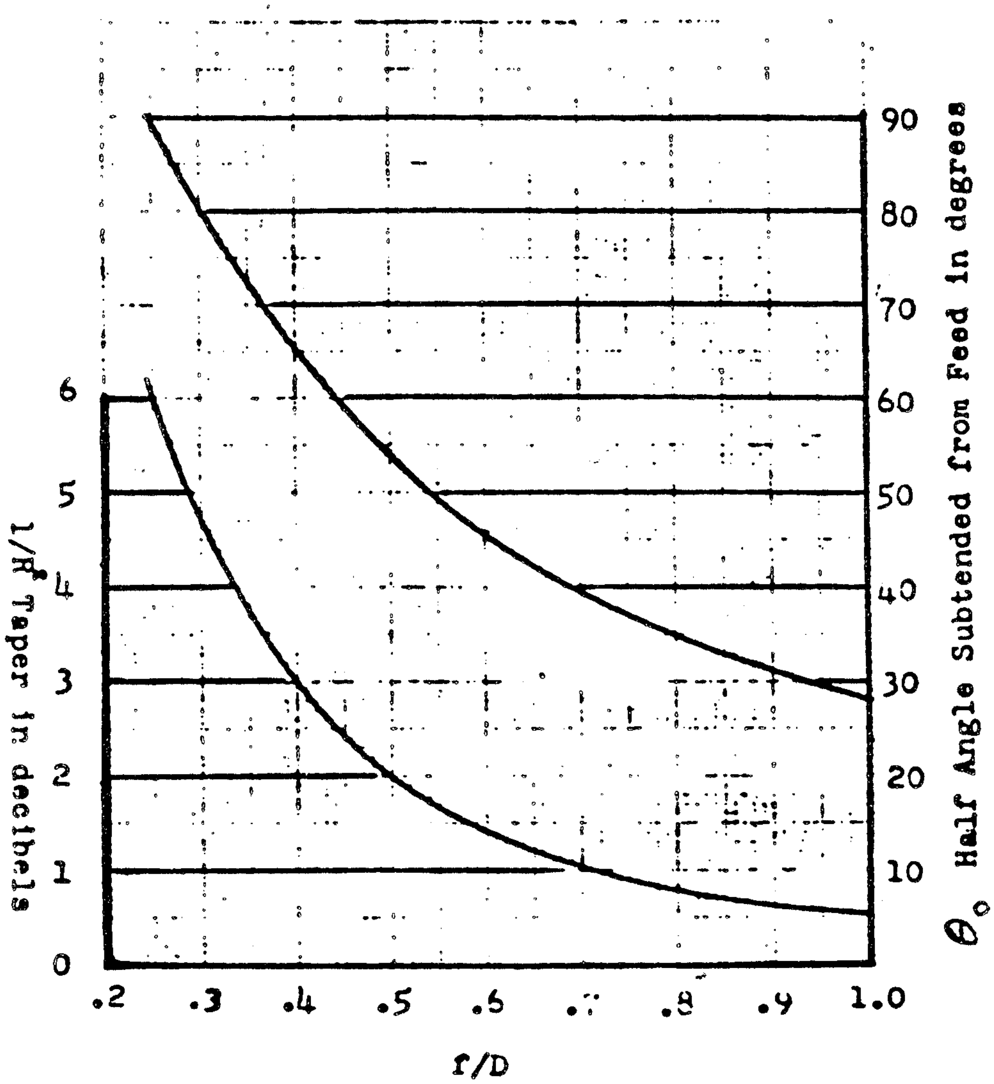
and, the normalized radiated electric field of the (IMU) feed can be represented with good accuracy by the expression ;

$$E(\theta) = 10^{-1.325\left(1 - \frac{\cos(\theta)}{\cos(\theta)} \cos(\theta)^{1.15}\right)}$$

Also the component of antenna temperature which is due to spillover alone when the background temperature is the constant Earth temperature is:

$$T_{a-sp} = T_{Earth} \frac{\int_{\theta_0}^{\pi/2} |E(\theta)|^2 \sin(\theta)\, d\theta}{\int_0^{\pi} |E(\theta)|^2 \sin(\theta)\, d\theta}$$

Figure 2 Subtended half-angle from feed to reflector as a function of f/D; and, $1/R^2$ illumination taper as a function of f/D.



$$\theta_o = 2 \arctan \left(\frac{1}{4 f/D} \right)$$

$$\text{Space taper (dB)} = 20 \log_{10} \left(\frac{1 + \cos(\theta_o)}{2} \right)$$

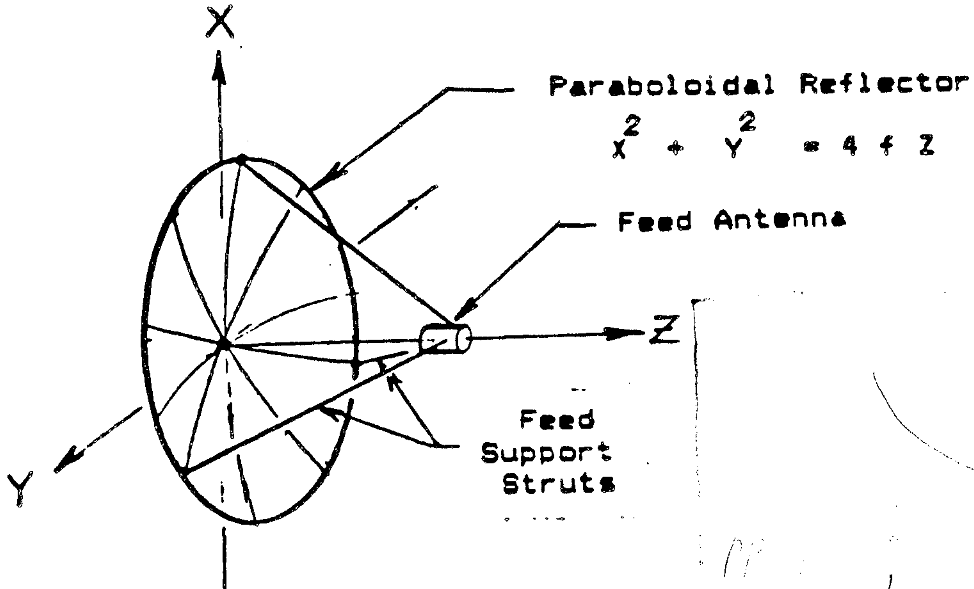


Figure 1a.

Parabola Geometry
in Polar Coordinates

$$R = \frac{2f}{1 + \cos\theta}$$

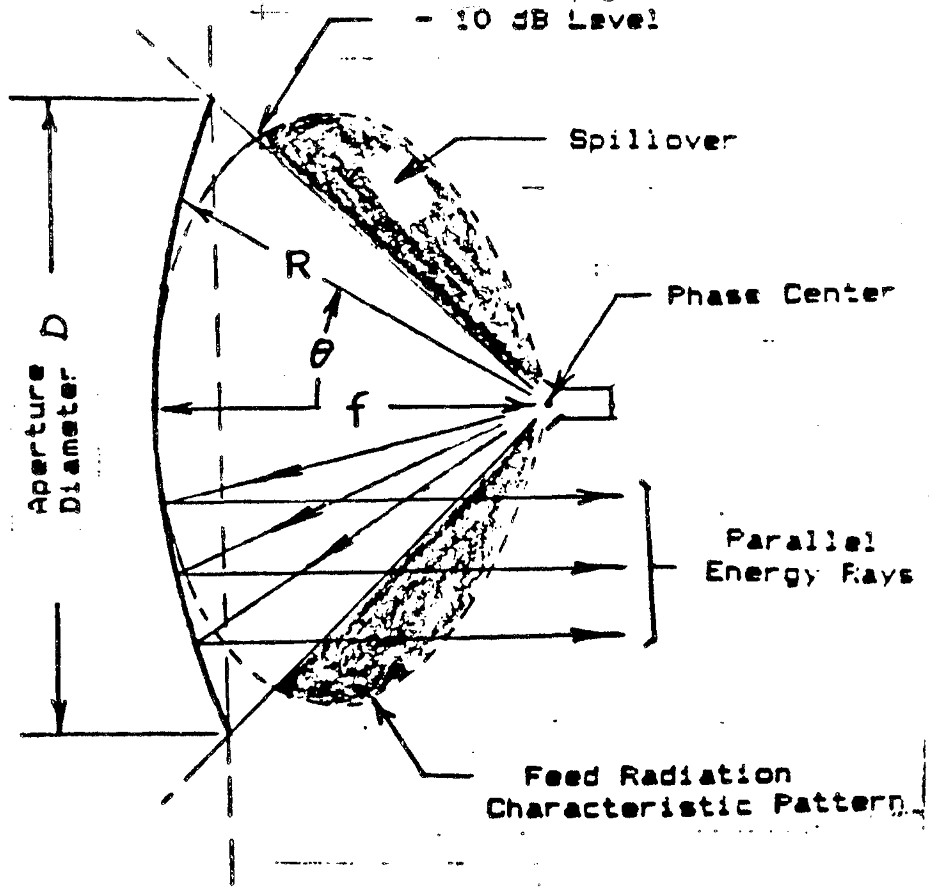
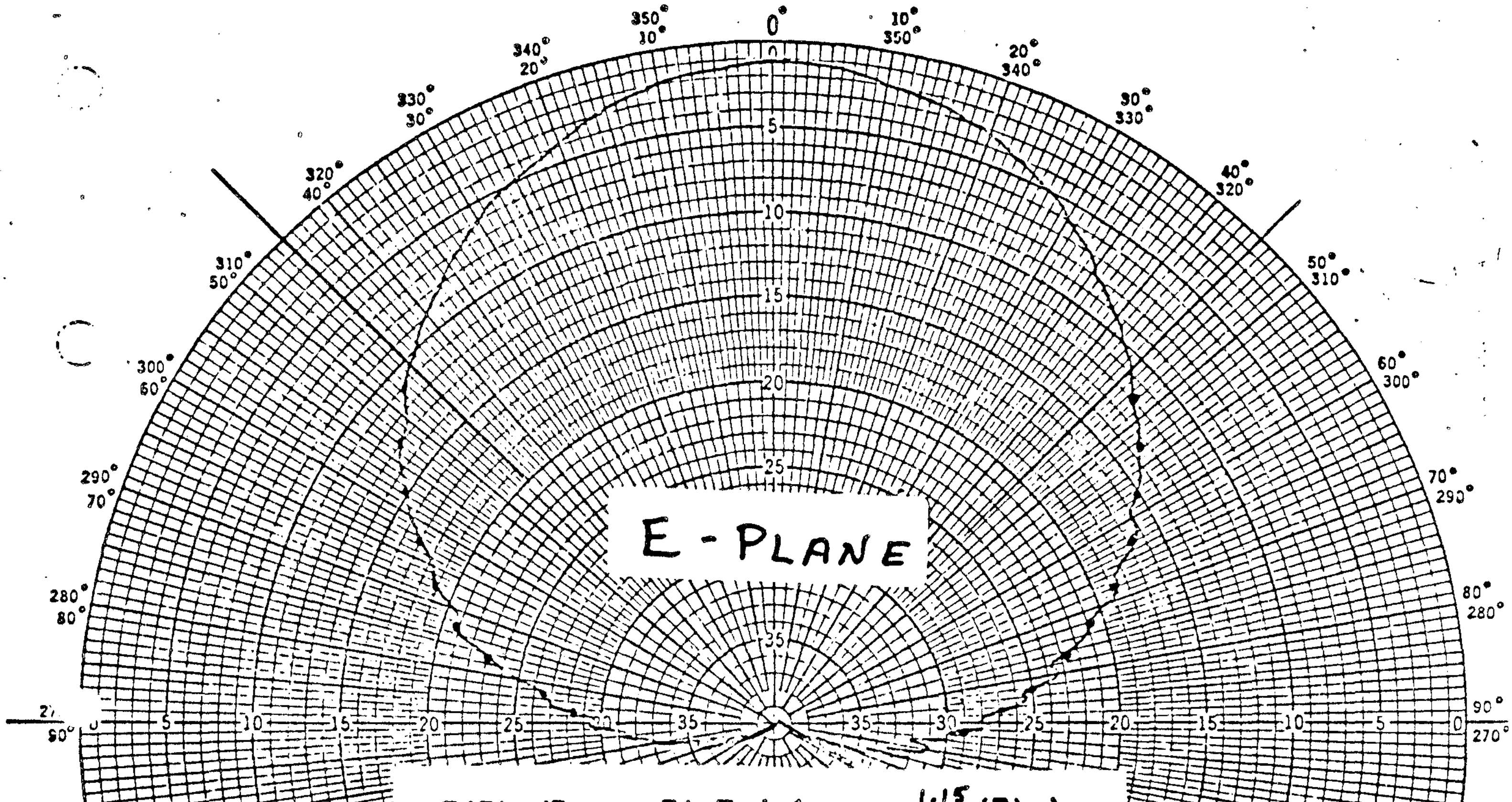


Figure 1b.



$$E(\theta)\ \mathrm{dB} = -\,26.5\,(1 - \cos^{1.15}(\theta))$$

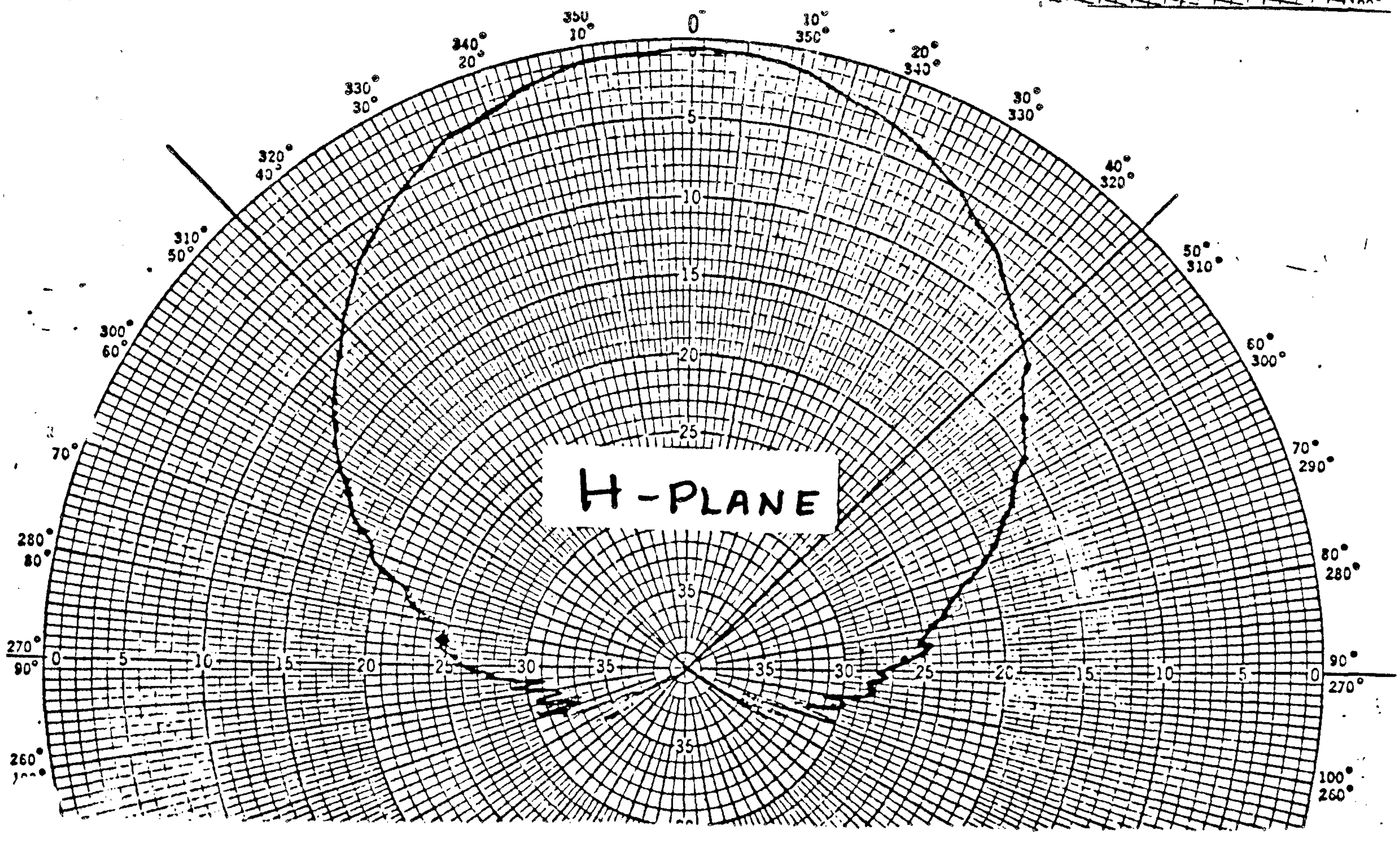


Figure 3. The measured radiation patterns, in the two principal planes, of a properly adjusted dual-mode (IMU) feed antenna, 1296 mc/s.

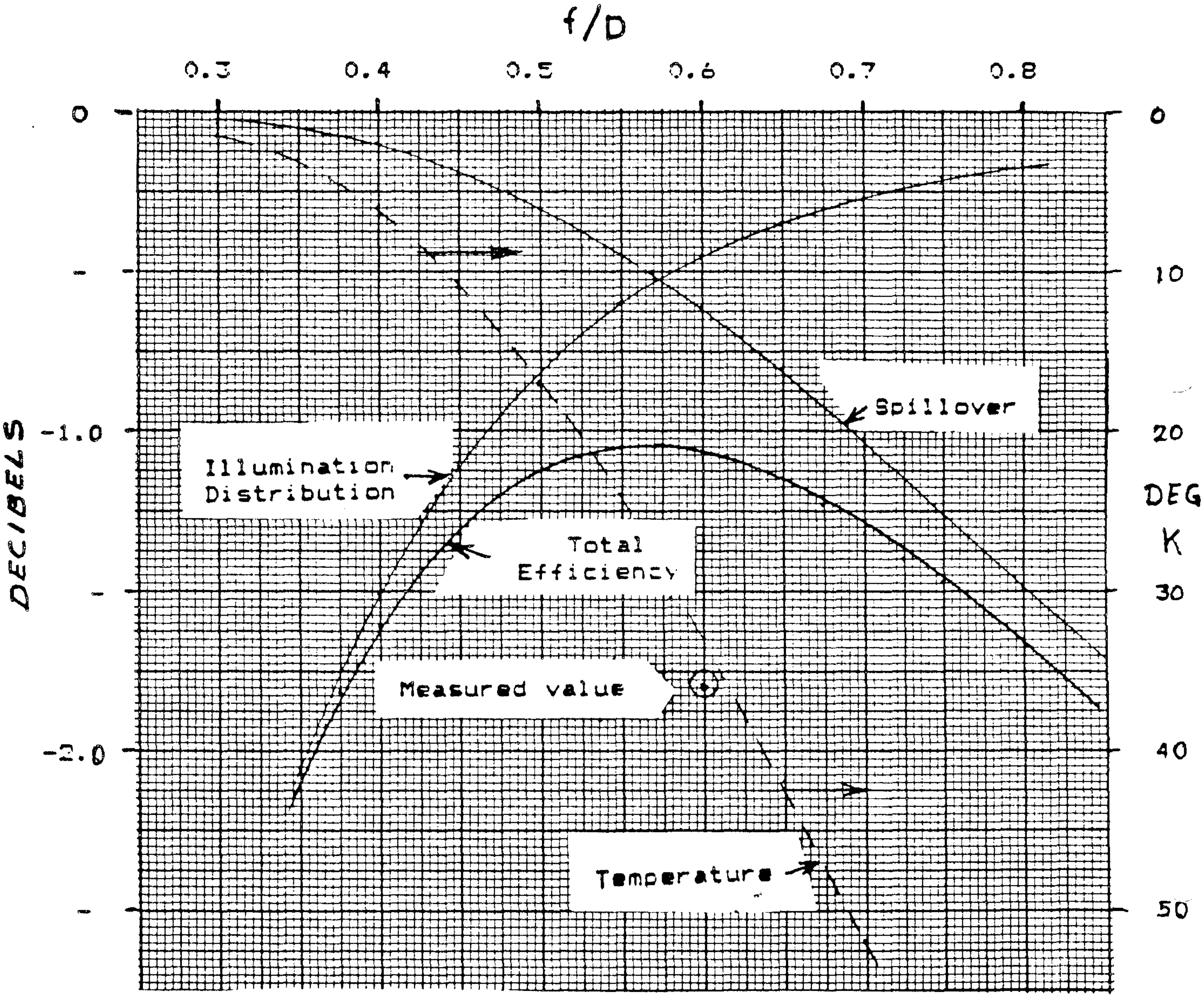


Figure 4. Computed efficiency and spillover temperature for a paraboloidal reflector with a dual mode (IMU) feed. The total efficiency curve can be used to determine loss in antenna gain as a result of using a paraboloid with a different f/D ratio than the optimum 0.56.

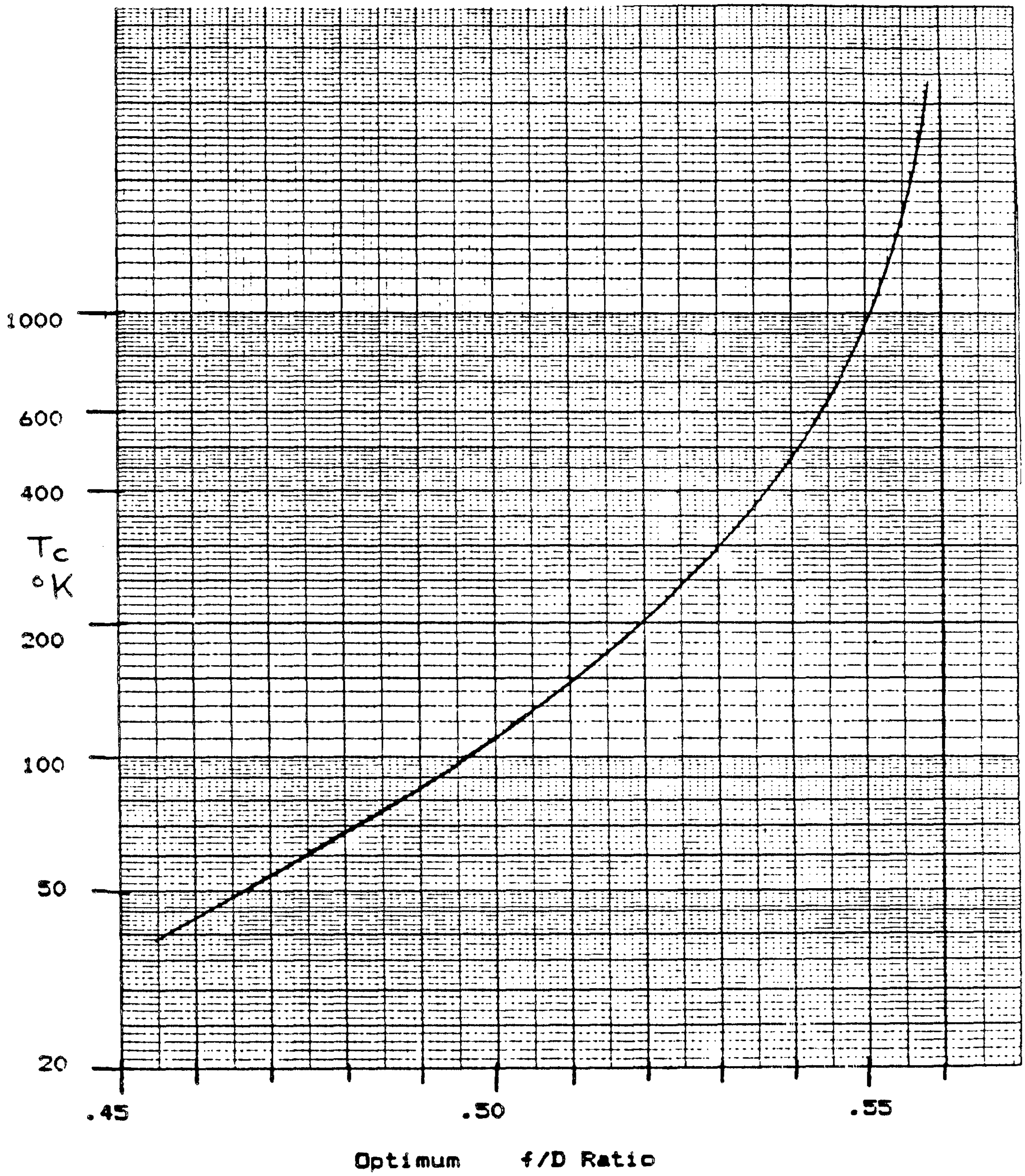
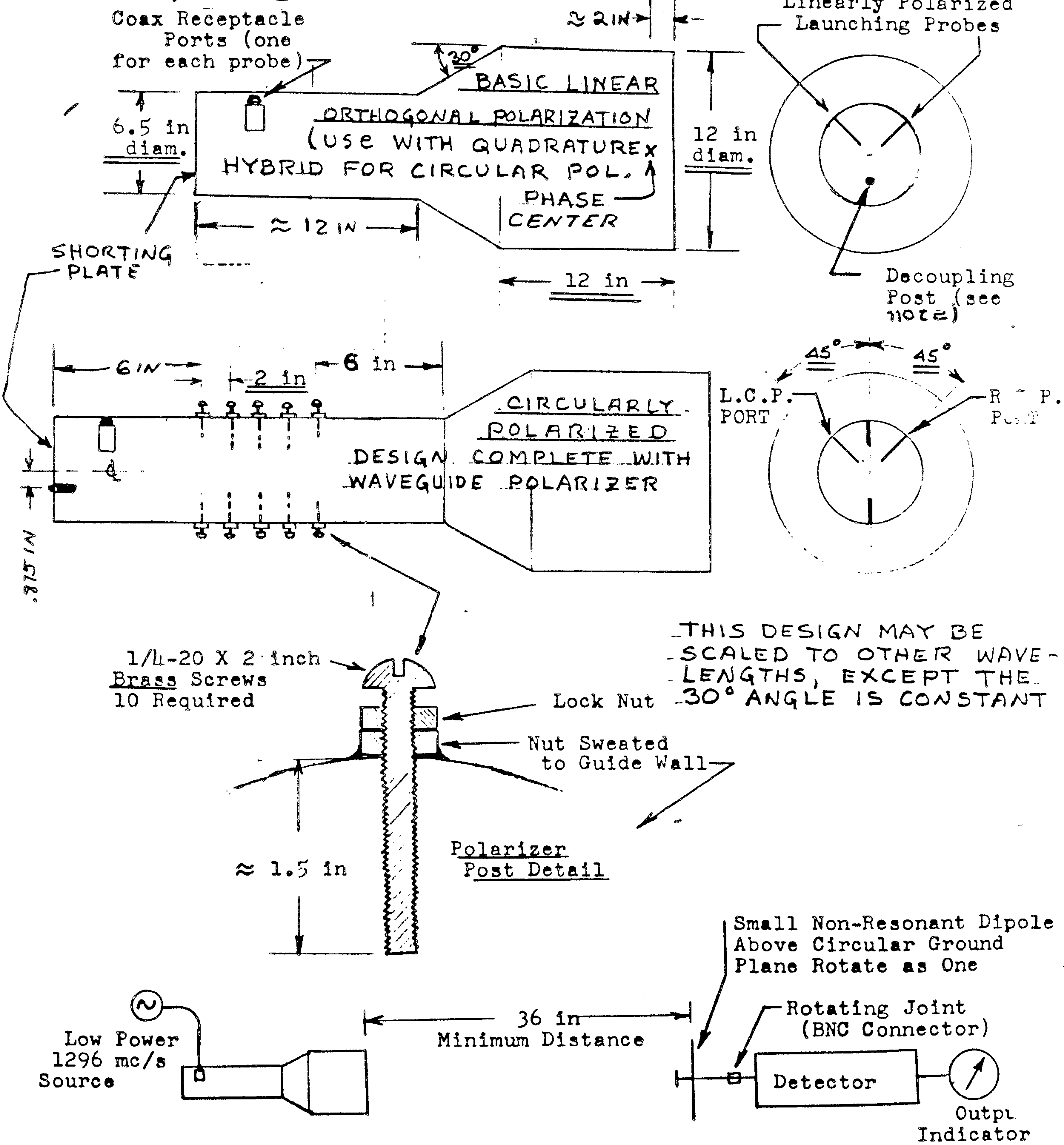


Figure 5. Computed optimum f/D ratio v.s. Tc, the component of Tsys not including spillover antenna temperature, Tsp. Tsys = Tsp + Tc . Optimum f/D computed for the maximum value of $(\eta_T)^2$ / Tsys.

DUAL-MODE FEED DESIGN FOR 1296mc/s W2IMU

FIGURE 6



Rotate sampling dipole slowly and determine ratio of maximum to minimum signal detected level. Be sure that the output indicator can display a 1 db change in level.

Figure 6. Notes Dec. l986

DUAL-MODE SMALL APERTURE FEED NOTES

The dual-mode small-aperture feed antenna makes use of the TE11 (dominant mode) and the TM11 circular waveguide modes which when properly phased and amplitude controlled at the radiating aperture, minimizes edge currents around the aperture rim. The result IQ a very circularly symmetric single lobe radiation characteristic pattern with side and rear radiation levels below - 35 dB. This feed when used with a paraboloidal reflector having an f/D = 0.56. will result in a reflector antenna system with overall measured aperture efficiency of 66 %.

Construction of this feed from cooper sheet is recommended for best performance, although brass sheet will give good results. Suitable cooper sheet is available from building supply houses as copper roof flashing. This is a soft copper sheet and should be worked carefully to maintain the accuracy of the circular guide sections. One or more stiffening rings may be cemented or soldered to the outside of the circular guide sections for mechanical rigidity, especially near the aperture.
Underlined dimensions on the drawing should be adhered to accurately. Axial alignment of the circular sections should be done carefully. A wooden frame jig is recommended.
All joints should be tight fitted butt seams with overlay tabs or strips soldered in-place on the outside for physical strength and electrical integrity. Clean excess solder from the inside of the feed. Solder is a poor and lossy conductor compared with copper.

The butt seams between conical and straight guide sections should be fitted carefully and secured with a multitude of bent tabs soldered on from the outside. Small brass screws may be used to initially hold a few tabs inplace, provided that the screws are cut off and filed flush on the inside of the structure.
Impedance matching at the coaxial drive ports is accomplished by adjusting the length of the probes incrementally and alsc bending the probes back or forth slightly, in an axial direction.
The nulling post is required to minimize cross coupling between the orthogonal probes dye the higher order asymmetric modes stirred up by the unbalanced probes. Adjustment of the position of the post must be done carefully to obtain cross coupling.

The nulling post is a 7/16 inch diameter brass or copper rod, 1.31 inches long and is located 0.875 inches off-center on the inside inside of the shorting end plate, as shown. It is secured with machine screw screwed into the post.

The probes are made of #14 copper wire.
Adjustment of the multiple screw. phase shift polarizer may be done using the set-up shown at the bottom of the drawing. The end pairs of screws should penetrate less than the others to effect a smoother impedance transition. There will be some interaction between all impedance and circularity adjustments.

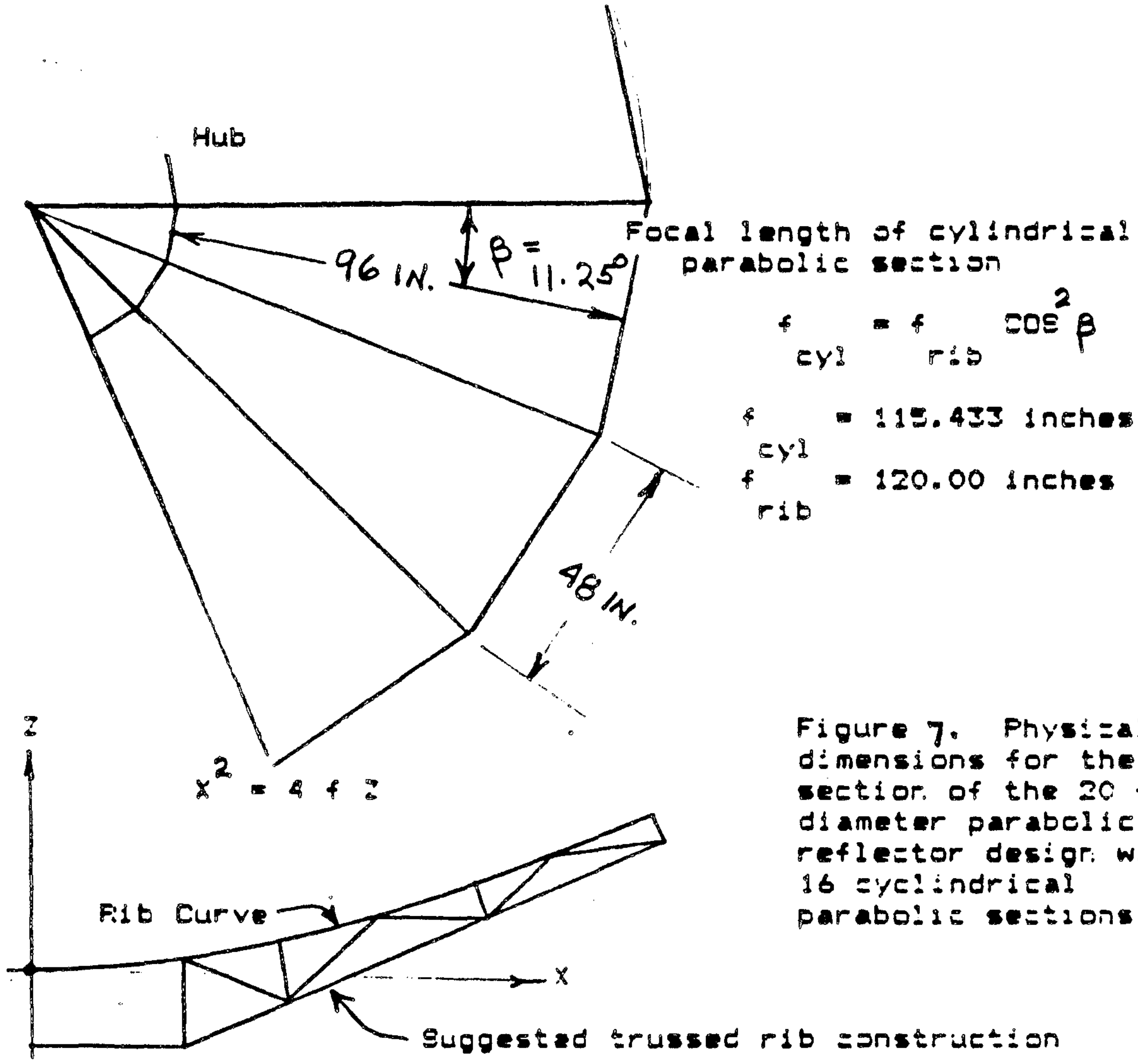


Figure 7. Physical dimensions for the rib section of the 20 foot diameter parabolic reflector design with 16 cyclindrical parabolic sections.

PARABOLIC RIB CURVE COORDINATES

inches		centimeters	
X	Z	X	Z
0	0	0	0
6	0.075	15.24	0.191
12	0.300	30.48	0.762
18	0.675	45.72	1.715
24	1.200	60.96	3.048
30	1.875	76.20	4.763
36	2.700	91.44	6.858
42	3.675	105.68	9.335
48	4.800	121.92	12.192
54	6.075	137.16	15.431
60	7.500	152.40	19.050
66	9.075	167.54	23.051
72	10.800	182.88	27.432
78	12.675	198.12	32.194
84	14.700	213.36	37.338
90	16.875	228.60	42.863
96	19.200	243.84	48.768
102	21.675	259.08	55.055
108	24.300	274.32	61.722

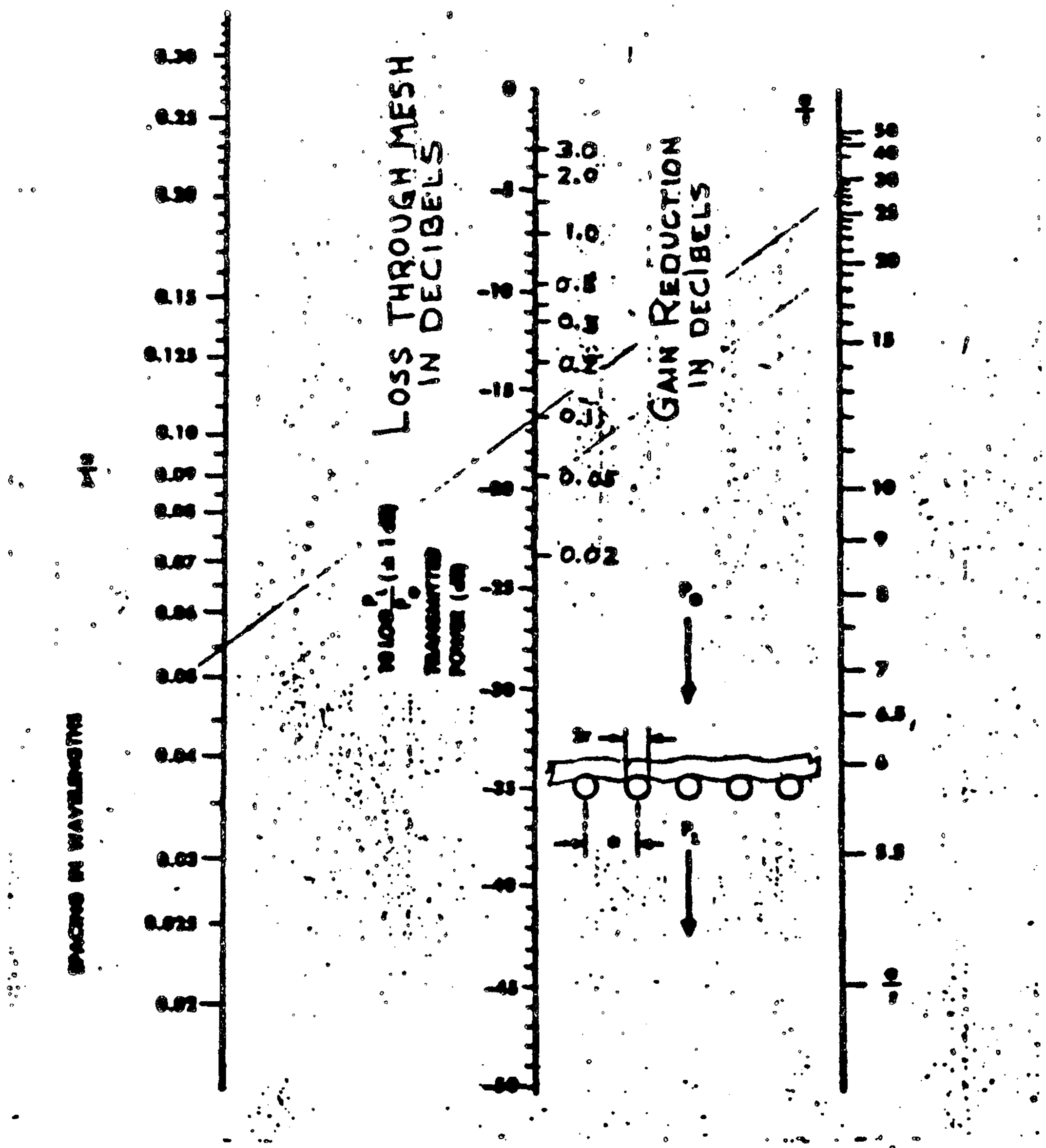
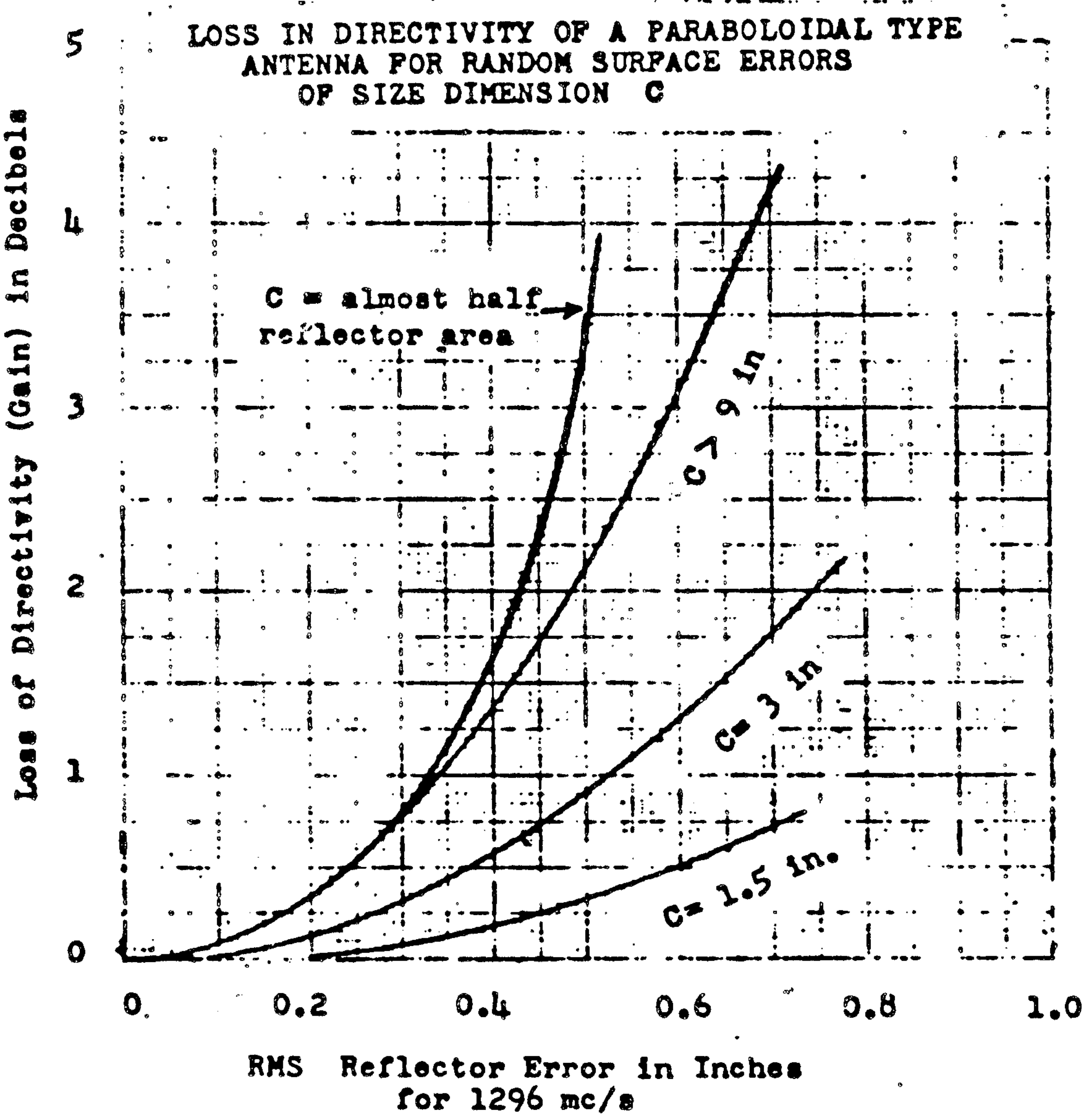


Figure 9. This nomograph relates transmission loss through a square mesh screen of conductive material, to the screen mesh and wire size. The resulting loss in antenna gain is also included for convenience.

As an example, suppose galvanized iron hardware cloth is selected for the surface material. The square mesh size is 1/2 x 1/2 inch and the wire diameter is 0.0340 inch. Therefore, a = 0.5 in., r = 0.0175 in. and λ = 9.13 in at 1296mc/s. Compute a/λ = .055 and a/r = 28.5. Connect these values on the appropriate scales with a straight line as shown above and read the transmission loss as -15.3 db. The corresponding loss in antenna gain for this material will be 0.1 db.

FIGURE 8



LOSS IN DIRECTIVITY OF A PARABOLOIDAL TYPE
ANTENNA FOR RANDOM SURFACE ERRORS
OF SIZE DIMENSION C
C = almost half
reflector area
C > 9 in
C= 3 in
C= 1.5 in.
5
4
3
2
1
0
0.
0.2
0.4
0.6
0.8
1.0
Loss of Directivity (Gain) in Decibels
RMS Reflector Error in Inches
for 1296 mc/s

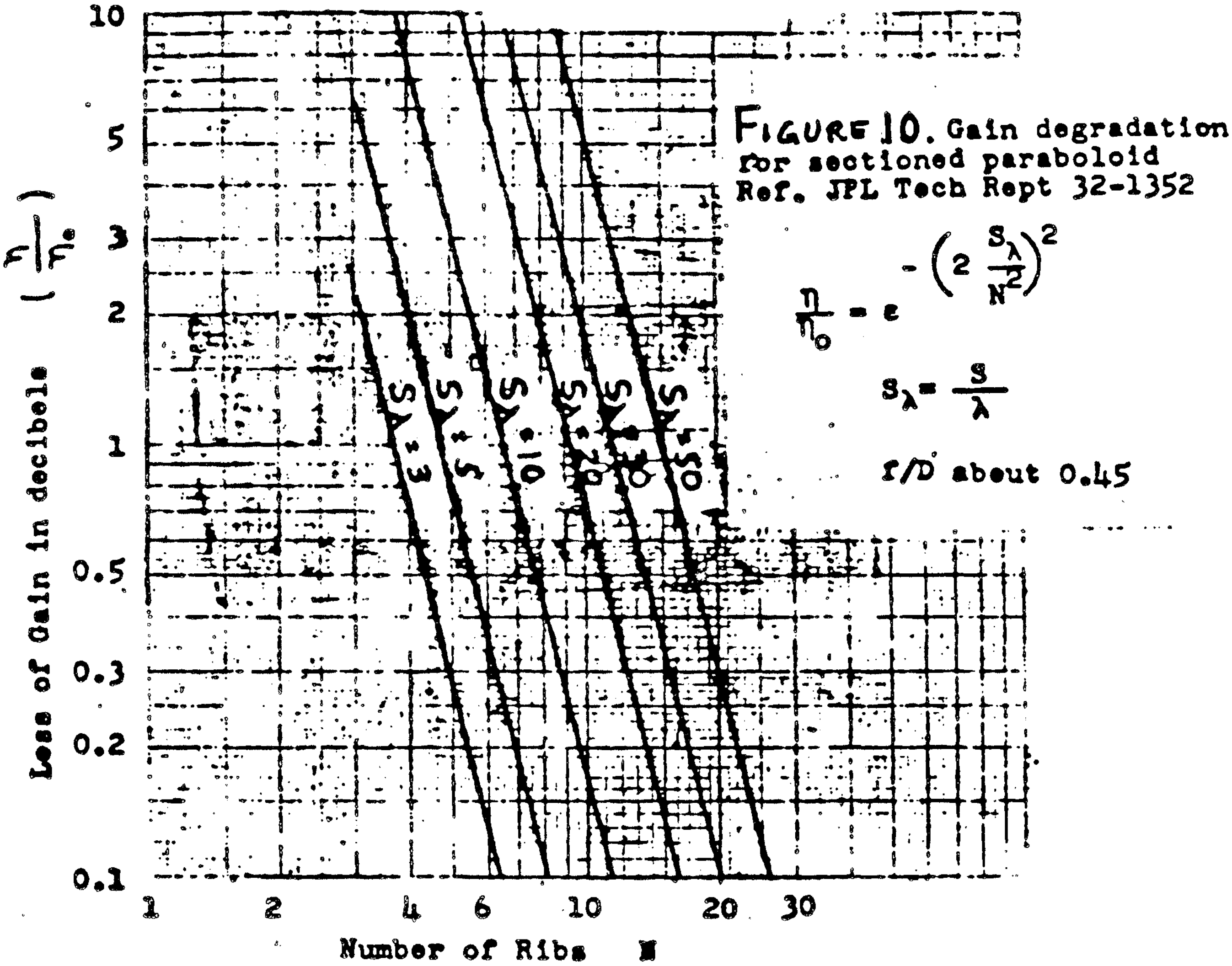
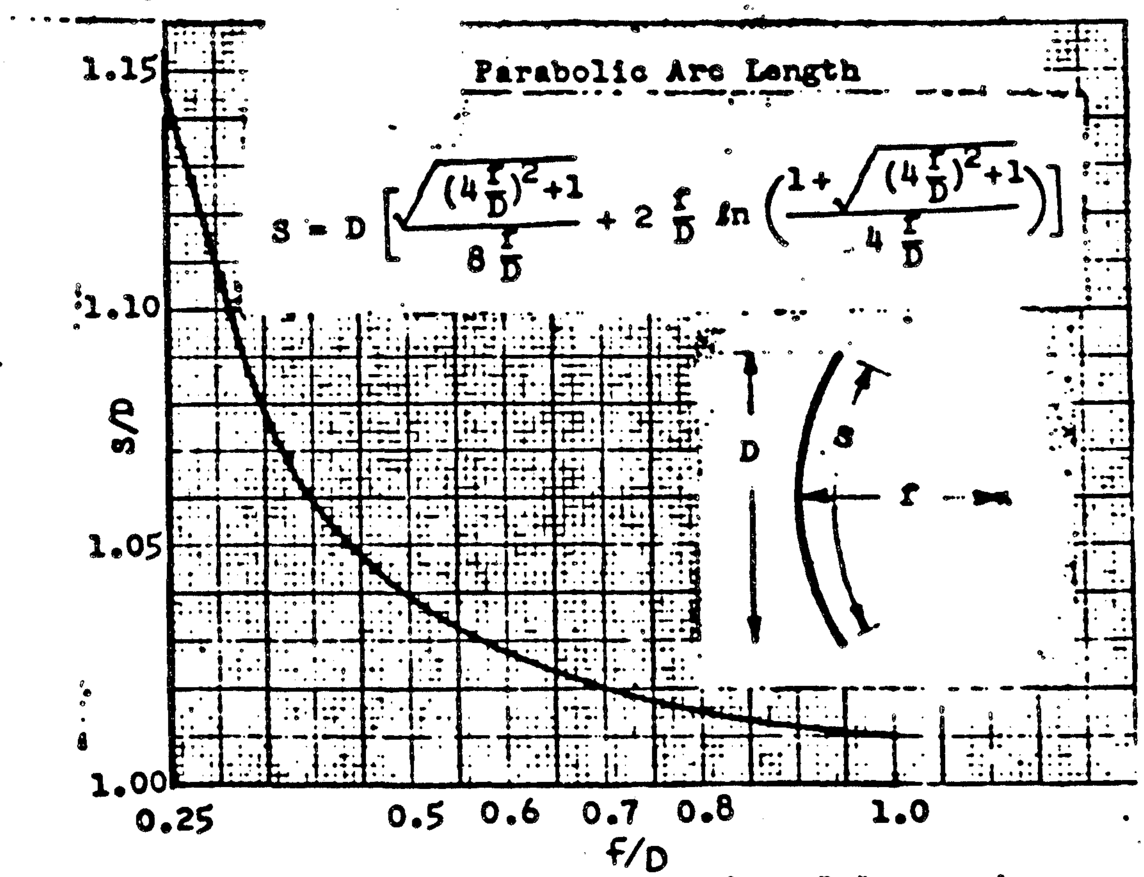
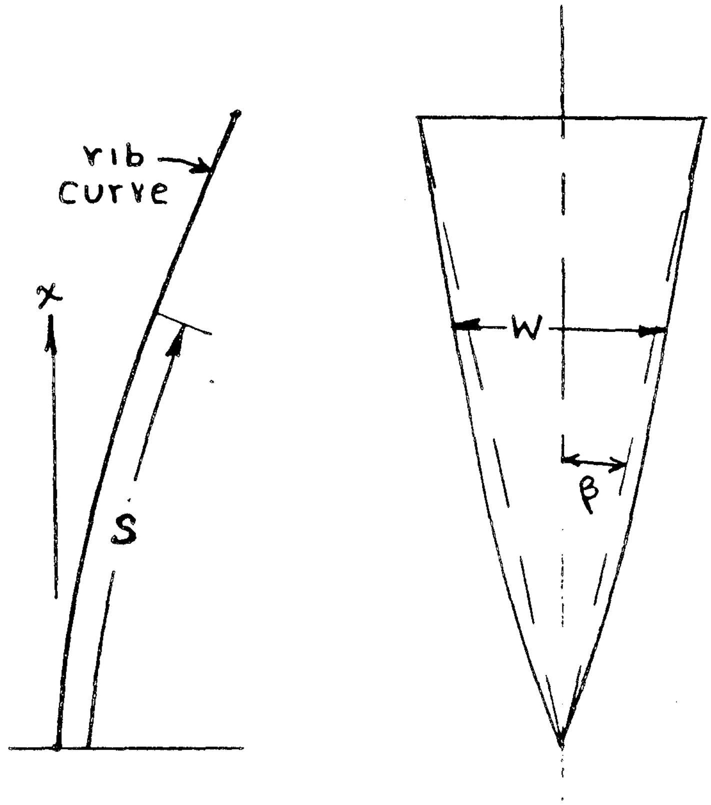


FIGURE 10. Gain degradation for sectioned paraboloid Ref. JPL Tech Rept 32-1352





$$S = \frac{1}{4f}\left[x\sqrt{4f^2 + x^2} + 2f^2 \, \ln\left(\frac{x + \sqrt{4f^2 + x^2}}{2f}\right)\right]$$

$$W = 2x \tan(\beta)$$

Where β is half the angle between ribs,
(for 16 ribs $\beta = 11.25$)

$\ln$ is the natural log (log to the base e)

Figure 11. Physical layout for petal surface section where sheet material with NO overlap is employed.